



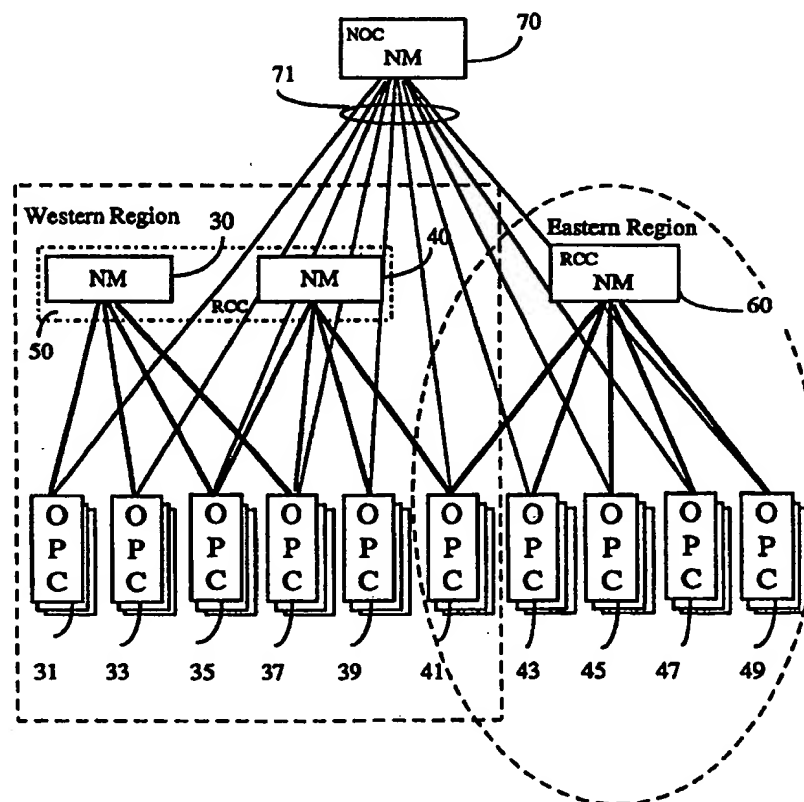
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(54) Title: ARCHITECTURE FOR NETWORK MANAGER

(57) Abstract

A distributed network management architecture, where a plurality of network managers share information about network elements by building the necessary infrastructure to discover alternate routes to element controllers when possible. A large number of network elements and operation controllers or managed object agents spans are simultaneously accessible to multiple graphical network browser instances on physical workstations. Each network manager can manage an element controller directly, through a direct connection, or indirectly, through an indirect connection to a second network manager which directly manages that element controller. As well, a plurality of telecommunication networks can be federated for transparently increasing the number of users and the reliability of each network. By allowing each network manager to be configured individually, more flexibility over both engineering and survivability is achieved.



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ARCHITECTURE FOR NETWORK MANAGER

BACKGROUND OF THE INVENTION

5 Field of the Invention

The invention is directed to a network architecture and more particularly to a distributed network management architecture sharing information about network elements and providing increased survivability.

10

Background Art

Network management has become increasingly complex in today's telecommunications networks. Currently, network managers directly managed element controllers, which could be operation controllers (OPCs) or managed object agents (MOAs). Intelligent network elements (NE) are software driven in every aspect from maintenance to control, to release upgrades. The management of these NEs requires a robust and highly efficient system which can process a large volume of data over a geographically distributed network. This highly efficient system must also provide network management tools for simplifying day to day operations and reduce service down-time.

In the current network architecture, a network manager generally manages a maximum number of 75 element controller pairs, an element controller supports up to four NMs, and an OPC can control up to 1200 network elements or networks. In addition, OPCs are limited processors that cannot handle more than four connections.

As customer transmission networks grow, so does the demand for the number of users who need access to the system. As such, the number of NEs becomes larger and they are more geographically dispersed. All these changes cause significant technological challenges to the nature of network management. No longer can the entire customer network be managed centrally from a single point, rather the need for distributed network management, locally and geographically, is a growing requirement. Additionally, customers wish to divide their network into different regions based on political or business boundaries. Quite frequently two or more regions overlap, presenting a challenge given the current engineering limits.

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United States patent No. 5,375,199 (Harrow et al. issued on December 20, 1994 to Digital Equipment Corporation) discloses a method and device for monitoring performance of a computer system, including a graphical user interface (GUI). The GUI is designed to provide historical or real time information on the system and also allows the user to interact with the information being viewed.

United States Patent No. 5,261,044 (Dev et al. issued on November 9, 1993 to Cabletron Systems, Inc.) relates to a network management system which performs fault isolation. The information relating to the network is displayed, the network entities being represented by icons. The user may select a prescribed area of an icon to obtain details regarding a particular aspect of the network entity represented by the respective icon.

However, these patents are not concerned with a distributed network management architecture designed for sharing information about the network elements and for allowing each NM to be re/configured individually to manage the element controllers on a per span basis.

SUMMARY OF THE INVENTION

An object of this invention is to provide an architecture and core network manager changes that allow a large number of network elements and operation controllers (OPCs), or managed object agents (MOAs) spans to be simultaneously accessible to multiple graphical network browser (GNB) instances on physical workstations.

It is another object of this invention to provide an increased survivability of network to network manager workstation communication in case of network outages, by building the necessary infrastructure to discover alternate routes to controllers when possible.

Accordingly, the invention comprises a method of managing an element controller of a telecommunication network using a plurality of federated network managers (NM), comprising the steps of connecting a first network manager (NM₁) to the element controller (EC) for directly managing the EC, and connecting a second network manager (NM₂) to the NM₁ for indirectly managing the EC.

The invention further comprises a method of federating a plurality of telecommunication networks for transparently increasing the number of users and the reliability of each network, comprising the steps of

directly connecting a first network manager (NM₁) to a first group of ECs, and connecting a second network manager (NM₂) to a second group of ECs for direct management of the respective first and second group of ECs, providing at each ECs of the first group a collector name server with information on the NM₁ and any other NMs directly managing the first group, and providing at each EC of the second group a collector name server with information on the NM₂ and any other NM directly managing the second group, establishing a connection between the NM₂ and the NM₁, upon a connection request from the NM₂ to a first EC of the first group, establishing an indirect connection between the NM₂ and the first EC for indirect management of the first EC through the NM₁, and upon a connection request from NM₁ to a second EC of the second group, establishing an indirect connection between the NM₁ and the second EC for indirect management of the second EC through the NM₂.

The invention also pertains to a method of federating a plurality of telecommunication networks for transparently increasing the number of users and the reliability of each network, comprising the steps of directly connecting a first network manager (NM₁) to a first group of ECs, and connecting a second network manager (NM₂) to a second group of ECs for direct management of the respective first and second group of ECs, providing additional direct connections between the NM₁ and selected ECs of the second group, and providing additional direct connections between the NM₂ and selected ECs of the first group, and providing at each ECs of the first group a collector name server with information on the NM₁ and any other NMs directly managing the first group, and providing at the EC of the second group a collector name server with information on the NM₂ and any other NM directly managing the second group.

Advantageously, NMs are configured to directly or indirectly manage element controllers on a per span basis. Indirect management allows the network manager user to specify the preferred method of managing the controller, reducing the total number of direct connections to an OPC, while giving more network managers visibility of the network.

Another advantage of the architecture according to the invention is self-healing, whereby a NM seeks other NMs to federate to, or promotes itself to direct management, when a NM directly managing an element controller fails.

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Scalability and survivability together mean increased numbers of users in a variety of locations, managing a larger number of network elements transparently and with higher reliability. Some element controllers are managed directly and even more, indirectly. Thus, the network architecture according to the invention allows management of up to ten thousand NEs, and up to seven hundred and fifty element controllers spans are simultaneously accessible.

Still another advantage of the invention is that by allowing each network manager to be configured individually, more flexibility over both engineering and survivability is achieved.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of the preferred embodiments, as illustrated in the appended drawings, where:

Figure 1 illustrates a network architecture with indirect and direct management of element controllers;

Figures 2 shows the increase in user capacity aspect of scalability according to this invention;

Figures 3 illustrate survivability scenarios: Figure 3A shows the points of connectivity loss, Figure 3B shows how management of an element controller is effected by an alternative network manager (NM) in case of connectivity loss, and Figure 3C illustrates a reluctantly promoted management path;

Figures 4A shows an exemplary network extending over two regions;

Figure 4B shows a first phase in the network growth comprising a network operation centre;

Figure 4C shows a second phase with an alternative network operation centre for survivability;

Figures 5A illustrates an example of evolution of the network architecture of Figure 4A, using indirect and direct management;

Figures 5B illustrates a further evolutionary stage of the network of Figure 5A using a federated connection between regional network managers, together with indirect and direct management;

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Figure 6A shows the evolution of network of Figure 5B, with network operation centers, federated, direct and indirect connections;

Figure 6B shows the architecture of Figure 6A, indirect connections removed;

5 Figure 7 shows one possible reconfiguration of the network of Figure 6A in case of failure of a regional network manager;

Figure 8 shows how the number of users of configuration shown in Figure 6B may be increased using scalability;

10 Figure 9 illustrates a further evolutionary stage for the network of Figure 6, designed for increased survivability;

Figure 10 shows the main components of the network manager and the element controller for implementing the architecture of the invention;

15 Figure 11 is a flow-chart for operation of the network to establish an indirect connection between a NM and an element controller; and

Figure 12 is flow-chart showing the operation of the network to re-establish a direct connection between a NM and an element controller.

20 DESCRIPTION OF THE PREFERRED EMBODIMENT

Definitions of some terms used in this specification are provided next, for a better understanding of the invention.

25 A network manager consolidates the OAM&P information collected from the controllers in the network. An element controller, which could be an operation controller (OPC) or a managed object agent (MOA), manages a span, or sub-network of NEs, providing functions to, and collecting information from the NEs within the span.

30 Scalability is defined herein as the ability to configure multiple network managers in such a way that they can share information about NEs, thereby increasing the number of NEs each network manager can manage without increasing the demands on the element controllers. Network managers configured in such a manner are called federated network managers, and as a whole, they are called a federation of network managers.

35 Scalability introduces the concept of indirect management of element controllers via another network manager. Figure 1 illustrates the principle of direct and indirect management according to this invention. A

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first network manager 1 directly manages OPCs (operation controller) 2. This is shown by direct management path (connection) 3. A second network manager 4 manages OPC 2 indirectly, as shown by indirect management path (connection) 5, via a federated connection 6 to network manager 1. The direct connections are illustrated throughout the drawings in solid lines, indirect connections are illustrated in dotted lines, and the federated connections, in double lines.

The number of element controllers that can be indirectly managed is larger than the number of element controllers that can be directly managed, thereby increasing the total number of network elements the network manager can manage. Conversely, there is no restriction on the number of network managers that indirectly manage an element controller. This is shown in Figure 2, illustrating OPC 2 managed through direct management paths by four direct NMs 1, each direct NM 1 (D-NM) being connected to 24 indirect NMs 4. In this way, each indirect NM 4 (I-NM) can indirectly manage OPC 2, resulting in a network architecture which allows management of up to ten thousand NEs, up to seven hundred and fifty element controllers spans being simultaneously accessible.

It is to be noted that a network manager only acts as an indirect server for a controller in a federation, if and only if, it is directly connected to that controller.

There is more to scalability than just sharing the information, scalability also provides a mechanism for increased survivability. Survivability is the ability for a federation of network managers to heal itself when there is a failure in the underlying transmission control protocol/internet protocol (TCP/IP) layer or in one or more of the network managers.

Figure 3A shows a simple network and two points of connectivity loss, for an exemplary network comprising NMs 1 and 8 directly managing OPC 2 and a third NM 4, indirectly managing OPC 2 through NM1. A first survivability scenarios disclosed in for an interruption of the management path 3 between OPC 2 and NM 1, a second scenario is disclosed for both an interruption of the management paths 3 and management path 7 between OPC 2 and a NM 8.

In the case of the 1st scenario, MN 4 cannot manage any more OPC 2 indirectly through NM 1, and it looks for an alternative

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management path. As NM 4 is federated with NM 8 over federated connection 9, NM 4 detects this alternative NM 8 and re-establishes an indirect management path to OPC 2 through NM 8, as shown in Figure 3B,

As indicated above, NM 4 has a preferred indirect connection to OPC 2. However, if both management paths 3 and 7 are interrupted, (second scenario), NM 4 cannot indirectly manage OPC 2. Now, NM 4 is forced to establish a direct connection because of the lack of an indirect connection. This connection is termed a direct reluctantly promoted connection. This connection/state is considered transitory, and NM 4 will attempt to restore back to indirect management at the first available opportunity. This scenario is illustrated in Figure 3C, where NM 4 promoted itself to directly manage OPC 2 through a reluctantly promoted management path 10.

Figures 4A to 7 show examples on how a network evolves as the number of the subscribers grows and as the user's requirements change. These scenarios also depict one way the phased delivery of scalability functionality could impact the evolution of network management in a company.

Let's assume that the size of the initial network has recently grown such that a network provider (NP) can no longer manage the entire network from a single network manager. When this point was reached, the responsibility for the network is divided between two regions, Eastern and Western regions, as shown in Figure 6A.

As well, let's assume that the Western region is expected to grow more in the near future, so the provider planned ahead and deployed two network managers 30 and 40 at the Western region control center (RCC) 50.

Each network manager directly manages a number of operation controllers 31, 33, 35, 37, 39, 41, 43, 45, 47, and 49. The description and drawings refer to OPCs for simplification, but it is to be understood that the invention applies also to other element controllers. The OPCs are deployed as necessary at various sites in the Western and Eastern region. Figure 6A also shows that some OPCs are managed by two network managers, for reasons that will be explained later. Thus, OPCs 35 and 37 are monitored by both network manager 30 and network manager 40, OPCs 41 are monitored by network manager 40 in the Western region and network manager 60 in the Eastern region.

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The explosive growth of the network of Figure 4A has led NP to realize that a network operations center (NOC) 70 need to be created for monitoring the entire network via direct connections 71, as shown in Figure 4B for the second phase of growth (NOC is also a NM). The regional network managers 30, 40 and 60 still exist for the day-to-day running of the network, while the NOC 70 is primarily used for off-hours support and demos to customers.

As each controller can be directly managed by maximum two network managers in the phase shown in Figure 4A, NP realizes that the number of connections per OPC must be increased from two to four for allowing more connections per OPC and more OPCs per network manager, for some controllers, such as OPC 35, 37 and 41 which each need three connections to them.

However, the solution of Figure 4B is temporary, for as soon as the number of OPCs in the network outstrips the maximum number that can be monitored from the network manager in the NOC, NOC 70 can no longer monitor the entire network. Increasing the number of element controller connections does nothing to enhance survivability, except increase the number of workstations that can monitor the network.

In addition, the site for NOC 70 can be a dangerous place, subject to earthquakes, volcanoes, power outages and crime. NP is concerned about survivability of the network and has built an alternative NOC 80 at a different site, to take over in disaster scenarios, as shown in Figure 4C. Additionally, the alternative NOC 80 can be used to off-load NOC 70 during peak demand and holidays. Unfortunately, by providing alternative NOC 80, provision of direct connections 81 to the OPCs exhausts the current maximum number of connections (four) for OPCs 35, 37, and 41.

Also, it is not possible to increase the number of the OPCs in the network of Figure 4B, since additional OPCs cannot be managed by NOC 70, the current engineering limit being 150 OPCs for a NOC, or 75 OPC pairs. As well, if for some reason, more network managers were required to monitor controllers 35, 37, and 41, this would be possible only using indirect management.

Not taking the NOCs into consideration just yet, indirect element controller management allows a reduction in the number of connections used at the sub-network controlling devices, as seen in Figure 5A. The number of direct connections in group 51 and group 53 has been

reduced from four to three by implementation of indirect connections 63 and 65. For implementing the indirect connections, a federated connection 61 has been set between NM 30 and 40. No changes have been made to the OPCs that each network manager directly manages, NM 30, 40 and 60 see the same controllers as before indirect management.

Next phase of growth provides for expanding the controllers managed by network manager 30 to include OPCs 37, 39 and 41, namely all OPCs in the Western region, as shown in Figure 5B. This was done by increasing the number of indirect connections in group 63 from one to three. Similarly, the OPCs managed by NM 40 include now all of the OPCs in the Western region, by increasing the number of indirect connections in group 65 from one to three. By indirectly connecting to OPCs 31, 33 and 35, more users have visibility of all of the NEs in the Western region.

In the next phase of network growth, NOCs 70 and 80 are given a view of the entire network by federating each network operating center with the regional network managers 30, 40 and 60, as shown in Figure 6A. This implies providing federated connections 73, 74 and 76 for connecting NOC 70 with regional network managers 30, 40, and 60, and federated connections 83, 84 and 86 respectively, for connecting NOC 80 with regional network managers 30, 40, and 60. Indirect connection 63 and 65 are configured as in the embodiment of Figure 5A. NOCs 70 and 80 do not directly manage any controllers, rather they manage all of the OPCs indirectly via the regional network managers. Implementing this is easy as it is simply a case of changing the existing direct connections to the OPCs, as shown in Figure 4C, into indirect connections.

A much cleaner picture of the connections in the network is shown in Figure 6B, which is Figure 6A with the indirect connections removed. In reality, the indirect connections are only logical connections, no surveillance or status information flows along these connections.

Unfortunately, it is not clear from Figure 6B the OPCs that each network manager indirectly manages. This is not important from a users' point of view, but from an engineering point of view, this picture clearly depicts the "nailed up" connections between the OPCs and the network managers, and the federated connections between the network managers.

Regarding how survivable this configuration actually is, let's assume that, for example, NM 60 is accidentally turned off. Now, NOCs 70 and 80 cannot indirectly manage the OPCs 41, 43, 45, 47, and 49 in the

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Eastern Region, and some form of direct management must be provided. One possible reconfiguration is shown in Figure 7, NM 60 with its direct connections is not shown for simplification and also because is not turned on. Controllers at 47 are now directly managed by NOC 70, and controllers
5 at 43, 45 and 49 are directly managed by NOC 80. NOCs 70 and 80 have created a federated connection 78 between them so that they can indirectly manage the OPCs the other is directly managing.

In general, the sharing of the load of managing the OPCs must not necessarily be divided equally between the network managers. In the
10 first phase of scalability, indirect connections should be attempted first to the network manager whose address is defined in a preference file, or lacking that, if sub-networks are implemented, to a workstation on the same sub-network as the indirect client. Either way, the number of simultaneous users of the NOC at each site has grown to exceed the
15 maximum supported by a single workstation. However, using scalability, it is a simple case to add another workstation in the site of, for example NOC 70, to allow more users, as shown in Figure 8.

All of the OPCs of Figure 8, but NM 41, now only have one connection to them, even though most of them have four network
20 managers managing them. The addition of a third NOC 90, would not change these numbers. Additional connections to OPCs are now no longer required to get visibility from different network managers, rather the additional connections are used to engineer better survivability configurations or to restrict access for whatever reasons.

Self-healing requires a NM to seek out other NMs to federate to,
25 or in the worst case, a network manager has to resort to directly managing the controller. Finding another network manager to federate to is the ideal self-healing process, because the healing process is quite short, and therefore configuring the network to try and take advantage of this is
30 highly desirable. One way to facilitate this objective is to have multiple network managers directly managing each OPC, so that federated network managers can quickly re-establish indirect connections. Eliminating single-points of failure is the primary goal. Ideally, the network managers directly managing each OPC should be connected via different routes and should be
35 geographically separated to eliminate the chance of environmental problems disabling both network managers simultaneously.

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The configuration of Figure 8 is still asymmetric in that the regional network managers still do not manage OPCs outside of their region. The resulting configuration is shown in Figure 9. On the other hand, while adding multiple direct connections in one federation potentially increases the recovery time in the case of a failure (it is assumed that initializing through a federated workstation will be quicker than connections to an OPC directly), the total number of controllers that can be managed across the federation will be decreased, as the engineering limits will strictly enforce the total number of direct connections per network manager.

Taking all this into account NP decided to increase the responsibility of the NOC workstations so that they share in the management of the controllers, as shown in Figure 9.

There are now multiple routes for a network manager to indirectly manage an OPC. For example, network manager 70 could monitor OPCs 49 via federated connection 76 to network manager 60, and the respective direct connection of group 55, or via federated connection 78 to network manager 80, and direct connection 88. Both routes directly manage OPCs 49.

The responsibility of each regional network manager is wisely split in the configuration of Figure 9, so that the effort is shared when a regional network manager is off-line. Thus, if network manager 70 were indirectly managing OPC 49 via network manager 60 and network manager 60 lost power, network manager 70 would switch to indirect management via network manager 80. If network manager 80 were indirectly managing OPC 41 via network manager 60, and network manager 60 lost power, network manager 80 would switch to indirect management via network manager 40. If network manager 70 were indirectly managing OPC 45 via network manager 80, the failure of network manager 60 would have no impact.

If subsequently network manager 40 failed, there would no longer be any network managers directly managing the OPCs 41 and one of network managers 30, 70, or 80 would have to directly manage OPCs at 41. For example, network manager 30 could reluctantly promote itself to manage OPCs at 41, network managers 70 and 80 would then indirectly manage this OPC via network manager 30. Similar recognition would occur for the other OPCs at 41 and the load of directly managing these

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orphaned controllers would be shared amongst the remaining network managers.

If NP wishes to enter a joint alliance with a long-distance provider LD, they must share management of a set of OPCs, let's say OPCs 41. Most probably, NP does not want LD to determine how the remaining of the network is managed. Conversely, LD does not want NP to determine how its network is managed. The solution is to configure separate networks to terminate at the OPC, and each company to configure their network manager to directly manage the shared OPCs. This does not change the NP configuration of the network of Figure 9 at all, except the number of free connections on each of the shared OPCs is reduced.

In the case of the multiple failure scenario above and shared OPCs at 41, when network manager 40 failed, network manager 30 would attempt to connect to the LD NOC 80. However, because the LD network manager is on another network, there is no IP connectivity to this network manager and network manager 30 is forced to resort to direct management of OPC 41, even though there is another network manager, namely NM 60, directly managing the OPC 41. Thus, configuring the IP network is important to prevent network manager 30 indirectly managing OPCs at 41 via the LD network manager.

Figure 10 shows the main components of a NM and an element controller relevant to this invention. Network manager 30 shown in Figure 10 is a workstation which provides nodal and sub-network OAM&P capabilities through a single view of transport and access nodes and directly manages a plurality of NEs that are connected to OPC 41. As indicated above, NM 30 may also indirectly manage a plurality of OPCs and can act as a client or server for other NMs.

NM 30 provides a graphical surveillance user interface (GUI) tool including a plurality of graphical network browsers (GNB) 12 and a configuration GUI named the graphical network editor (GNE) 14. According to the invention, whether an element controller is directly or indirectly managed has no bearing on the performance or behaviour of the GNB 12 and is transparent to the GNB user.

Network managers are configured by the user via GNE 14 to directly or indirectly manage element controllers on a per span basis. Provisioning what controllers the network manager is interested in by specifying their IP address, is done in the GNE 14 as usual. The

fundamental difference is that the operator may now select the preferred management path, direct or indirect. To this end, GNE 14 selects the element controller and the preferred management path, i.e. direct or indirect. An indirect server manager component (ISM) 34 and an indirect client manager component (ICM) 36 are the core of the scalability and survivability solution. These components are integrated into the existing network manager collector process and provide the ability to service incoming requests from other network managers as an indirect server, and to similarly establish connections to other network managers as indirect clients.

ISM component 34 provides a mechanism to service indirect management requests from other network manager workstations. This is accomplished by creating a TCP/IP server at a well known port for processing the incoming requests.

The information flow between NM 30 as a directly managing server and a client NM is provided over a federation network interface (NNI) 32. Once the interface is negotiated, the indirect server 34 waits for requests from the client NM for the specific OPC/MOA entities that the requester is interested in. Only requests for controllers that are currently being managed via a direct connection to the OPC or MOA such as OPC 41 will be considered by ISM 34.

When this negotiation is complete, information flow for the controller pair is transmitted from ISM 34 to the indirect client NM. Only one TCP/IP connection is maintained per communicating network managers. This information includes core network element information, such as name identifiers, rate, type and support information, existing active alarms, and asynchronously delivery alarm state transitions, performance monitoring support information, sub-network configuration data, and network element connectivity or association status.

The role of ICM 36 is to find a path to a controller if the management path is specified by GNE 14 as indirect. It does this by first querying that OPC for the list of currently connected network managers, then attempting to register indirectly through another network manager. If there are no direct managers available, ICM 36 will attempt to reluctantly promote itself to direct management of that controller.

When presented with a choice of two or more possible routes for indirect management, ICM 36 will choose a preferred route according to a

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preference algorithm, if it is available. The preference algorithm uses an indirect access database (IAD) 38, and performs for example the following operations:

First, IAD 38 is consulted by ICM 36 for the list of preferred paths. If
5 there is a match, that path is attempted first. For example, an entry in IAD 38 of form '47.105' means that presented two possible indirect paths '47.105.9.219' and '47.45.4.48', '47.105.9.219' will be selected first.

Next, if sub-networks are implemented, and if one of the routes is a network manager on the same sub-network as the client, that route is
10 attempted first.

Last, a random selection is made if no preferred path resulted from the above operations.

This strategy allows for an additional level of control over indirect management, allowing optimal network paths (where there is
15 more bandwidth, for example) to be established first, if available.

IAD 38 is also consulted by ICM 36 before allowing access to an indirect manager client. This database comprises of a list of IP addresses or sub-networks that requests will or will not be accepted from. This is used to facilitate the creation of independent federations which do not share
20 management information or interact with each other. It is also used to ensure a predictable environment during software testing. The database 38 is modifiable using a simple configuration tool accessible from the existing administration tools.

The effect of increasing the total number of NEs impacts on the
25 total amount of network configuration data that must be stored, including active alarms for the entire network. This requirement places additional burden on the NM physical resources. The underlying assumption in evaluating the impact on NM, however, is that only a relatively small portion of that data will ever need to be duplicated through user interfaces
30 at any one given instance in time.

A network data cache (NDC) may be used in another embodiment of the invention for managing and storing data previously shared by all GNB's into a single cache entity, available for reading by all network manager processes. NDC is used to write various data in a shared
35 area to be accessed in a read-only fashion by all other network manager processes. The goal of NDC is to achieve an order of magnitude savings as compared to the existing GNB 12 and GNE 14 process under similar loaded

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conditions, thus minimizing or eliminating the requirement for additional hardware to achieve the engineering limits.

A critical component of the architecture according to the invention is implemented in the collector name server (CNS) 46 component provided at each OPC/MOA workstation. CNS 46, whose interface is implemented through the existing regulation browser (REGB) process on the OPC, provides a mechanism to query the OPC server for the existing directly connected NM workstations, necessary for enabling ICM 36 to select a path for indirect management.

10 In the current design, access to the NE and OPC/MOA user interface is accomplished by using the primary network manager collector to controller interface to add entries in the appropriate control files on the controller, which then allows the network manager unauthenticated remote execution of selected processes, if a concurrent entry for the
15 invoking client UNIX userid is present on the controller.

As a design requirement, each indirect connection accounts for the equivalent of two directly managed element controller spans. This parameter is enforced and has been deduced by engineering studies on the existing architecture. An interface is provided by ISM 36, to manage and
20 keep track of these indirect connections for the purpose of engineering the entire NM collector process. Specifically, because of the possibility of a failure of one or more indirectly managing workstations causing the client to attempt direct connections to the controller and potentially well exceed its maximum number of direct connections, this number in conjunction
25 with the current number of primary and backup direct connections will be used to enforce engineering limits in the software.

Additional changes should be made to the existing components of the NM. For example messaging optimizations between GNB 12 and the components of the NM must be provided as a result of these changes. The
30 controller list dialogue should also be substantially modified to accommodate the now larger volume of controllers, as well as reflect the routing decisions being made by the network manager, such as IP address of network manager serving an indirect connection, indirect or direct preferred state, and the current actual management state of each controller.
35 This information should also be visible to GNB users in a read only fashion.

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It is suggested that T1 or equivalent bandwidth as a minimal requirement to sustain acceptable performance between federated network managers. Given the basic data provided, the entire network bandwidth can be engineered to account for shifts in management responsibility that will happen when survivability aspects are considered. Any extra bandwidth required to maintain acceptable performance when shifts in management happen will largely depend on how the federation is setup and how many spans are being managed concurrently across the federated connections.

Figure 11 illustrates how an indirect connection is established in the network of Figure 9. Let's suppose that NM 70 requests communication with OPC 41 as shown in step 100. NM 70 queries OPC 41 via CNS 46 regarding the NM directly connected to this OPC, in step 110. If a plurality of direct NMs is found, such as NM 40 and NM 60 in step 120, a preference algorithm selects a preferred direct NM in steps 130-150.

When specifying a preferred direct connection, an attempt is made to register directly with the element controller 41 as usual. If both NM 40 and NM 60 failed, or none of NM 40 and NM 60 directly manage OPC 41, as illustrated along the NO branch in step 120, NM 70 would negotiate a self-promotion with the element controller to directly manage it, as shown in step 220. Information now flows between NM 70 and OPC 41, step 230, and other network managers could then indirectly manage the element controller 41 via this promoted network manager.

If the connection was established through a reluctantly promoted network manager, NM 70 will attempt to restore back to indirect management at the first available opportunity, as shown by the timer in step 240.

As indicated earlier, if NM 40 and NM 60 are operational to directly manage OPC 41, NM 70 must select one of these two NMs ($i=1$ or $i=2$) for indirectly managing OPC 41. The preference algorithm initiated in step 130 is designed to take into account the network architecture and also the client's demands. In steps 140 and 150 NM 70 determines which one of NM 60 and NM 40 has a preferred direct connection to OPC 41 and establishes a management path to this preferred NM. If a preferred direct connection is not available, as shown by branch 'NO' of block 150, NM 70 determines which one of NM 60 and 40 has a preferred reluctantly promoted connection to OPC 41, as shown in steps 200 and 210. Step 160

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shows the flow of information between NM 70 and OPC 41, once a management path has been established in steps 130, 140, 150, 200, and 210.

Any changes in management path initiated under the control of the federation will attempt to happen transparent to the GNB user, in other words without indicating a loss of connectivity for those network elements affected (normally done by turning the affected icons blue). This is called a no-blue switch.

A direct benefit of scalability is the inherent survivability that comes from the distributed management of the network. Survivability is implemented using a revertive N:1 strategy that allows multiple network managers in the federation to maintain management of element controllers which can no longer be managed by another network manager for reasons such as workstation or network outages. This is accomplished by an indirect client, such as NM 70 in the example of Figure 9, seeking out another server, such as NM 60 in the federation, if its current server becomes unavailable, or if a controller becomes unavailable from the point of view of the current directly managing server. The NEs operate as in the case of establishing an indirect connection, shown in Figure 11.

If a network manager workstation cannot directly manage an element controller, it can no longer facilitate indirect management of the controller for federated network managers. Federated network managers that used to indirectly manage that controller will now have to find alternate means of doing the management, directly or indirectly. As part of the self healing process, the affected network managers will first try to find another network manager directly managing the NE controller and establish a federated connection to it for the purpose of indirectly managing that NE controller. In the above example, NM 40 will be selected by the preference algorithm in step 130.

Figures 12 is flow-chart showing the operation of the network to re-establish a direct connection. In step 300 NM 70 requests a direct connection with OPC 47. If the registration to this OPC is full, i.e. the element controller already serves four NMs, as shown by the 'YES' branch in step 310, the query is repeated at regular intervals of time, shown in step 320, until OPC 47 becomes available, shown by branch 'NO'. In this case, information flows between NM 70 and OPC 47 along direct connection 77, as illustrated in step 330.

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Any changes in management path that are initiated by a real loss of connectivity, such as an outage of the supporting indirect server workstation, or the lack of network connectivity to an OPC or MOA workstation, will always be indicated to the user.

5 If a network manager preferred management route is direct, and it cannot establish a direct connection because the controller registration is full and all other connections are preferred direct, it will not demote itself to indirect. It is the responsibility of the federation manager to configure the network with no more than the maximum number of direct
10 connections supported for that controller.

 Indirect management of an element controller does not mean IP connectivity is no longer required between the network manager and the element controller it manages indirectly. In fact, IP connectivity is required to set up indirect management in the first place. IP connectivity is also
15 required for on-demand functionality such as remote login, PM query, remote inventory, shelf level graphics, and electronic software delivery. For increased survivability, IP connectivity is required to allow the network manager to directly manage the element controller if for some reason it cannot find another network manager directly managing the specific
20 device.

 Next, some survivability scenarios are discussed for the configuration of Figure 9.

 In the event of a loss of connectivity between an indirect NM, let's say NM 40 for OPC 33, and its client NM 80, the client will attempt to
25 reconnect indirectly via another manager whose principally configured as a direct manager. This is accomplished by requesting the list of connected network managers from CNS 62 of OPC 33, and posting a request to the preferred server.

 If there are no direct managers available, for example NM 30 is
30 turned "off", NM 80 will attempt to reluctantly promote itself to direct management of OPC 33 if there are any connections available.

 The role of ICM 38 continues after recovery by continuously attempting to recover a connection via an indirect path. When a route becomes available, a switch over is completed without presenting a loss of
35 connectivity to depending applications. By always attempting a return to this steady state, some level of control over communicating entities is preserved.

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It is to be noted that this switch over may also impact other workstations in the federation, who may be managing indirectly via the reluctantly promoted path. The switch over is mandatory, although all attempts will be made to re-establish routes without presenting a loss of connectivity to the application.

In the event of a direct NM, such as NM 30 losing connectivity to an OPC/MOA, such as OPC 33, the indirect clients NM 70 and NM 80 will be notified. A client, say NM 80 will then attempt to connect to OPC/MOA 33 and establish a connection via an alternate route, for example through directly connected NM 70, hence surviving a connectivity problem due to a network outage that only affected its current indirect server. If there is no TCP/IP connectivity between the indirect client workstation and the controller (i.e. the controller is down, or invisible due to the same network outage), it will continue to attempt indirect connections until a path becomes available.

In the event of a network manager outage, it is possible for more than one federated network manager to establish a direct reluctantly promoted connection to the same controller. Because this may affect federation engineering, it is an undesirable state.

To overcome this state, reluctantly promoted connections in the federation continuously attempt to demote themselves, although one reluctantly promoted direct connection must always remain to ensure one server is available for the federation.

Other specifications for the network managers that should be noted follow.

If an optimal route is not available at the time of connection resulting in the selection of another path, the ICM will not revert once the optimal path becomes available.

Also of note is that multiple Ethernet interfaces are not supported; if a workstation is part of multiple sub-networks due to more than one LAN interface, the preferred path will only be discovered if this is true because of the first or default interface, as specified in the IP host map.

When specifying indirect management for a span which contains both a primary and a backup controller, an attempt will be made to use the same indirect server for both the primary and backup controllers. Otherwise, the connection path for each controller is determined separately, which may result in the primary and backup getting their

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management information from different indirect servers, or even both or one of the pair reluctantly promoting itself to satisfy its desire to find a path to that controller.

5 The architecture allows for the future evolution of the messaging interface between the NM and the controller which will allow the indirect server to communicate addressing information about indirect clients to the controller, allowing the indirect clients to make login requests directly to the OPC or MOA.

10 Because of the increased amount of data required to setup a large federation interested in most or all of each others directly managed spans, a tool could be provided to remotely retrieve the preferred directly managed spans of any network manager in the federation and apply any or all of those spans as preferred indirect in the local network manager's domain.

15 Several areas of functional improvements are possible beyond the above description, as the previously mentioned load balancing when surviving a failure. The load on each NM is defined by the number of controllers it directly manages. This is configured manually by the user in the GNE and can be re-defined at any time, so that all NM directly manage
20 their fair share of OPCs.

In a true load balancing application, after a recovery has been completed, the network managers will communicate their current loads and hand-off direct management of element controllers to less heavily loaded workstations until a uniform load is achieved. This hand-off
25 should not impact functionality and should be transparent to GNB users.

In indirect management there is no balancing, the load is distributed randomly based on which network manager is the first to claim a direct connection to each OPC, influenced by the network topology and the distribution of the network managers within that topology. It is
30 anticipated that given the random nature of this algorithm, a uniform distribution will be achieved.

While the invention has been described with reference to particular example embodiments, further modifications and improvements which will occur to those skilled in the art, may be made
35 within the purview of the appended claims, without departing from the scope of the invention in its broader aspect.

WE CLAIM:

1. A method of managing an element controller of a telecommunication network using a plurality of federated network managers (NM), comprising the steps of:
 - (a) connecting a first network manager (NM₁) to said element controller (EC) for directly managing said EC; and
 - (b) connecting a second network manager (NM₂) to said NM₁ for indirectly managing said EC.
2. A method as claimed in claim 1, wherein step (b) comprises:
 - providing at said EC a collector name server with information on all NMs directly managing said EC;
 - providing at said NM₁ an indirect server manager unit, and
 - providing at said NM₂ an indirect client manager;
 - requesting at NM₂ a connection with said EC, comprising querying said collector name server to locate a NM that directly manages said EC and detecting NM₁;
 - establishing a federated connection between said NM₂ acting as an indirect client for said NM₁, and said NM₁ acting as an indirect server for said NM₂; and
 - establishing signalling between said NM₂ and said EC over an indirect connection through said NM₁.
3. A method as claimed in claim 1, further comprising the step of (c) connecting a third network manager NM₃ to any of said NM₁ and NM₂ for indirectly managing said EC.
4. A method of federating a plurality of telecommunication networks for transparently increasing the number of users and the reliability of each said network, comprising the steps of:
 - (d) directly connecting a first network manager (NM₁) to a first group of ECs, and directly connecting a second network manager (NM₂) to a second group of ECs said NM₁ and NM₂ for direct management of said respective first and second group of ECs;

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(e) providing at each ECs of said first group a collector name server with information on said NM₁ and any other NMs directly managing said first group, and providing at each EC of said second group a collector name server with information on said NM₂ and any other NM

5 directly managing said second group;

(f) providing a federated connection between said NM₂ and said NM₁;

(g) upon a connection request from said NM₂ to a first EC of said first group, establishing an indirect connection between said NM₂ and said first EC for indirect management of said first EC through said NM₁; and

(h) upon a connection request from said NM₁ to a second EC of said second group, establishing an indirect connection between said NM₁ and said second EC for indirect management of said second EC through said NM₂.

15

5. A method as claimed in claim 4, wherein step (g) comprises:

(i) receiving said connection request from said NM₂ to said first EC and detecting in said collector name server that NM₁ directly manages said first EC;

20

(j) establishing a direct connection between said NM₂ acting as an indirect client for said NM₁, and said NM₁ acting as an indirect server for said NM₂ over said federated connection; and

(k) establishing an indirect connection between said NM₂ and said first EC through said NM₁.

25

6. A method as claimed in claim 4, wherein step (h) comprises:

(l) receiving said connection request from said NM₁ to said second EC and detecting in said collector name server that NM₂ directly manages said second EC;

30

(m) establishing a direct connection between said NM₁ acting as an indirect client for said NM₂, and said NM₂ acting as an indirect server for said NM₁ over said federated connection; and

(n) establishing an indirect connection between said NM₁ and said second EC through said NM₂.

35

7. A method as claimed in claim 4, further comprising the steps of:

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providing additional direct connections between said NM₁ and selected ECs of said second group; and
providing additional direct connections between said NM₂ and selected ECs of said first group.

5

8. A method as claimed in claim 5, wherein said step (j) comprises providing at said NM₁ an indirect server manager unit for serving incoming requests from said NM₂, and providing at said NM₂ an indirect client manager unit for requesting indirect management of said first EC.

10

9. A method as claimed in claim 6, wherein said step (m) comprises providing at said NM₂ an indirect client manager unit for requesting indirect management of said first EC and an indirect server manager unit for serving incoming requests from said NM₁.

15

10. A method of federating a plurality of telecommunication networks for transparently increasing the number of users and the reliability of each said network, comprising the steps of:
directly connecting a first network manager (NM₁) to a first group of ECs, and connecting a second network manager (NM₂) to a second group of ECs, said NM₁ and said NM₂ for direct management of said respective first and second group of ECs;
providing a federated connection between said NM₁ and said NM₂;
providing additional direct connections between said NM₁ and selected ECs of said second group, and providing additional direct connections between said NM₂ and selected ECs of said first group; and
providing at each ECs of said first group a collector name server with information on said NM₁ and any other NMs directly managing said first group, and providing at each EC of said second group a collector name server with information on said NM₂ and any other NM directly managing said second group.

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35

11. A method as claimed in claim 10, further comprising providing at each of said NM₁ and said NM₂ an indirect server manager

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unit for serving incoming requests from other NM, and an indirect client manager unit for requesting indirect management of an EC.

5 12. A method as claimed in claim 11, further comprising, upon receiving a connection request from said NM₁ to said second EC applying a preference algorithm for establishing a preferred management path, and establishing a connection between said NM₁ and said second EC over said preferred management path.

10 13. A method as claimed in claim 12, wherein said preference algorithm comprises:

 querying said collector name server of said second EC to locate a directly managing NM, and detecting said NM₂;

 determining if said NM₂ is available for communication with
15 said second EC;
 whenever said NM₂ is available,

 establishing said preferred management path as an indirect connection from said NM₁ to said second EC through said NM₂;
 whenever said NM₂ is not available,

20 assuming a reluctantly promoted state at said NM₁ to directly manage said second EC, and establishing said preferred management path as a reluctantly promoted direct connection from said NM₁ to said second EC; and

 demoting said NM₁ from said reluctantly promoted state when
25 said NM₂ recovers, and establishing said preferred management path as said indirect connection; and

 continuously attempting to demote any NM from said reluctantly promoted state.

30 14. A method as claimed in claim 11, further comprising providing a network operation center (NOC-NM) and directly connecting said NOC-NM with each of said NM₁ and MN₂ over a respective federated connection.

35 15. A method as claimed in claim 14, further comprising providing at said NOC-NM an indirect server manager unit for serving

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incoming requests from said NM₁ and said NM₂, and an indirect client manager unit for requesting indirect management of an EC.

16. A method as claimed in claim 14, further comprising the
5 steps of providing additional direct connections between said NOC-NM and selected ECs of said first and said second groups.

17. A method as claimed in claim 16, further comprising, upon
receiving a connection request from said NOC-NM to an EC, applying a
10 preference algorithm for establishing a preferred management path, and establishing a connection between said NOC-NM and said EC over said preferred management path.

18. A method as claimed in claim 17, wherein said preference
15 algorithm comprises:
 querying said collector name server of said EC to locate a directly managing NM and locating NM₁;
 determining if said NM₁ is available for communication with
said EC;
20 whenever said NM₁ is available,
 establishing said preferred management path as an indirect connection from said NOC-NM to said directly managing NM and to said EC;
whenever said NM₁ is not available,
25 assuming a reluctantly promoted state at said NOC-NM to directly manage said EC, and establishing said preferred management path as a reluctantly promoted direct connection from said NOC-NM to said EC; and
 demoting said NOC-NM from said reluctantly promoted state
30 when said NM₁ recovers, and establishing said preferred management path as said indirect connection; and
 continuously attempting to demote any NM from said reluctantly promoted state.

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19. A method as claimed in claim 11, further comprising connecting said NOC-NM with an alternative NOC-NM through a federated connection.

5 20. A method as claimed in claim 19, further comprising the steps of providing additional direct connections between said alternative NOC-NM and selected ECs of said first and said second groups.

10 21. A method as claimed in claim 20, further comprising, upon receiving a connection request from said alternative NOC-NM to an EC, applying said preference algorithm for establishing a preferred management path, and establishing a connection between said alternative NOC-NM and said EC over said preferred management path.

15 22. A method as claimed in claim 17, wherein said preference algorithm comprises:
 querying said collector name server of said EC to locate a directly managing NM and locating NM₁ and NM₂;
 determining if any of said NM₁ and NM₂ is available for
20 communication with said EC and selecting a provisioned favourite between said NM₁ and NM₂;
 whenever said favourite NM is available,
 establishing said preferred management path as an indirect connection from said NOC-NM to said EC through said favourite
25 NM;
 whenever said favourite NM is not available,
 assuming a reluctantly promoted state at said NOC-NM to directly manage said EC, and establishing said preferred management path as a reluctantly promoted direct connection from said NOC-NM to said
30 EC; and
 demoting said NOC-NM from said reluctantly promoted state when said favourite NM recovers, and establishing said preferred management path as said indirect connection.

35 23. A method as claimed in claim 11, further comprising providing an indirect access database (IAD) at said NM₁ for storing the

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network addresses of all NMs which are indirect clients of said NM₁, and the network addresses of all NMs which are indirect servers of said NM₁.

24. A method as claimed in claim 23, further comprising:
- 5 protecting each network address in said IAD with an associated network provider ID; and
- configuring said telecommunication network for use by a plurality of network providers, according to said associated network provider ID.

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FIGURE 1

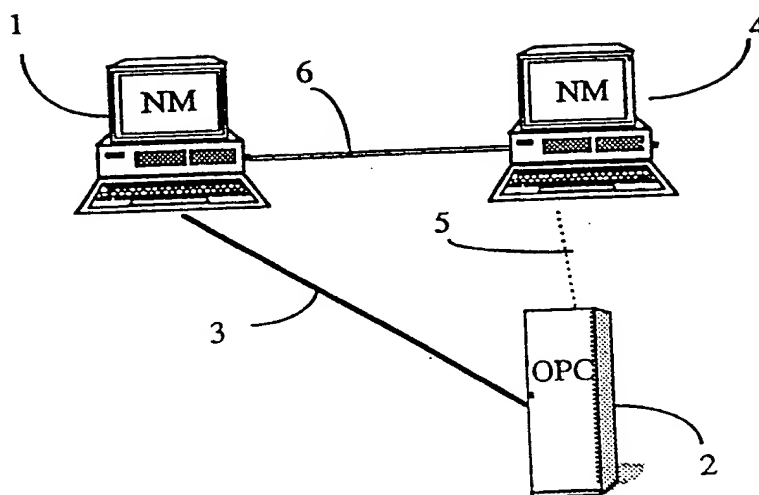
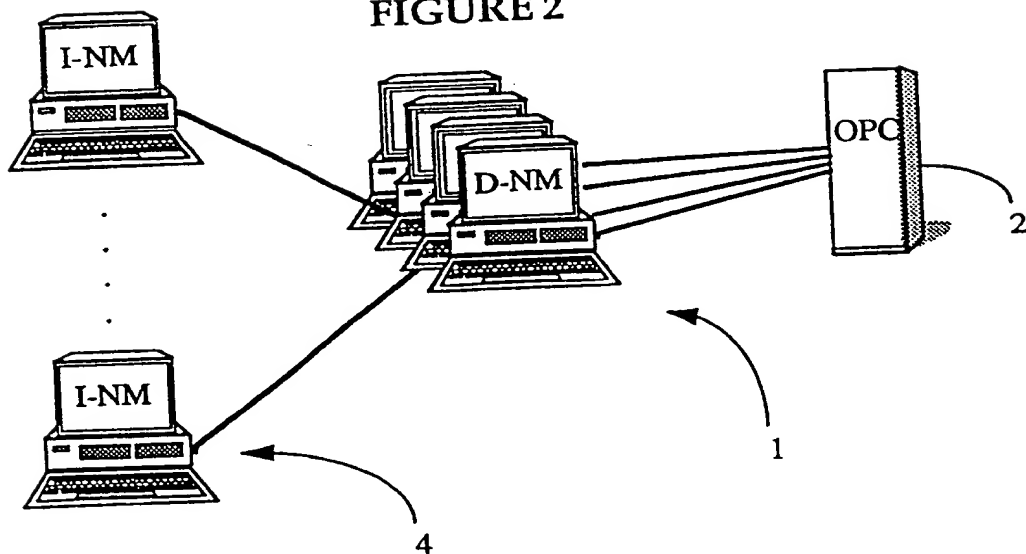


FIGURE 2



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FIGURE 3A

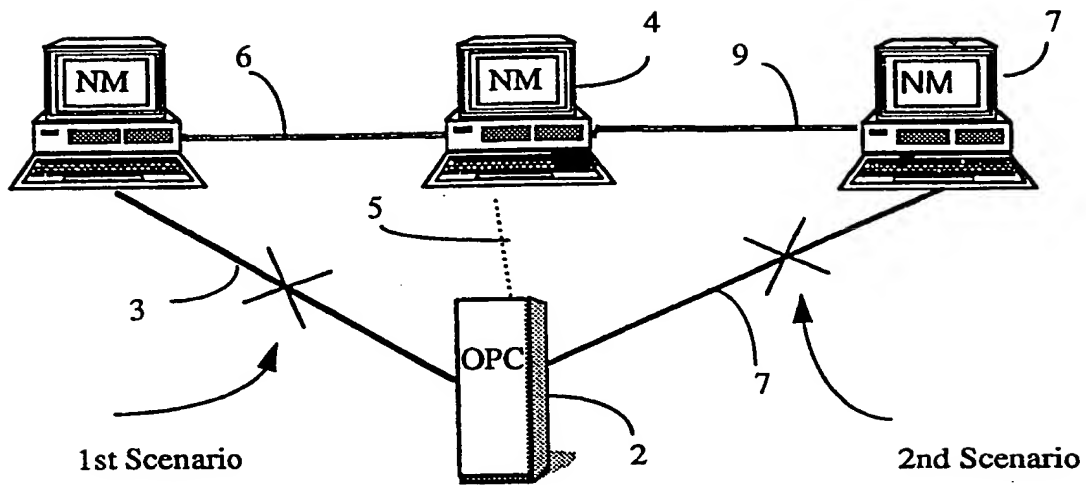
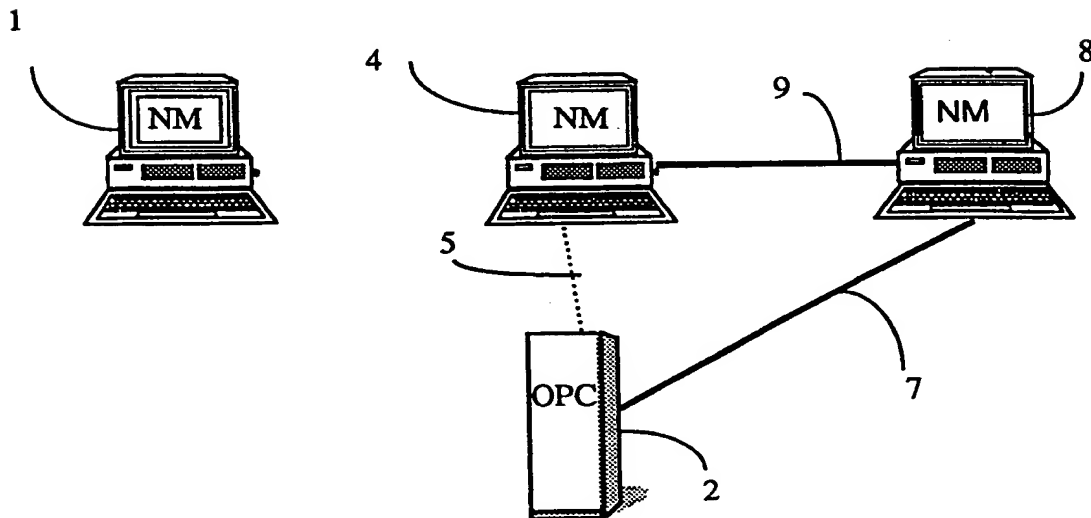


FIGURE 3B



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FIGURE 3C

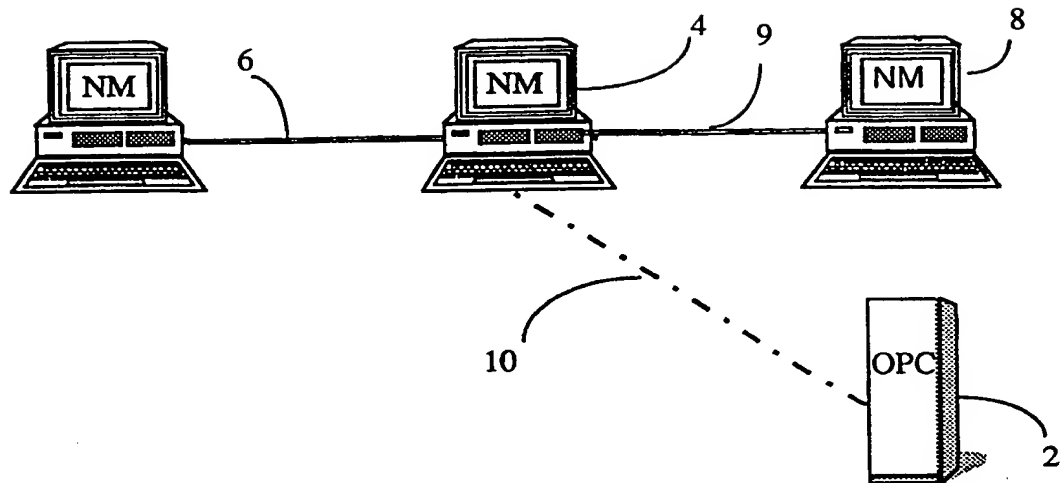
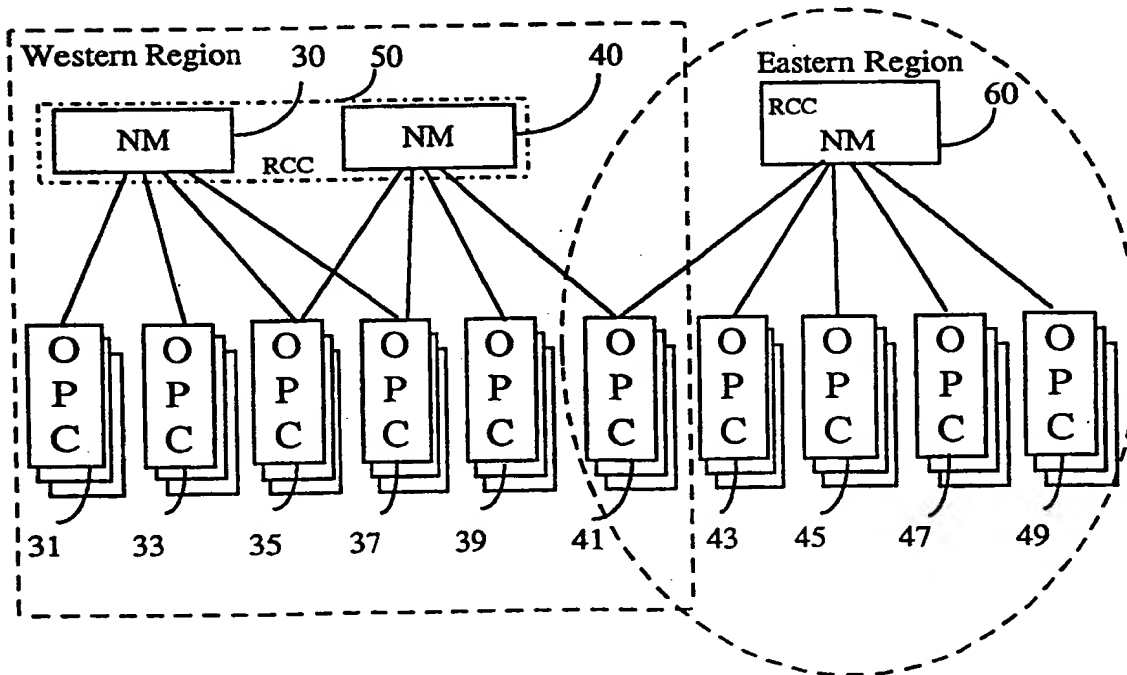
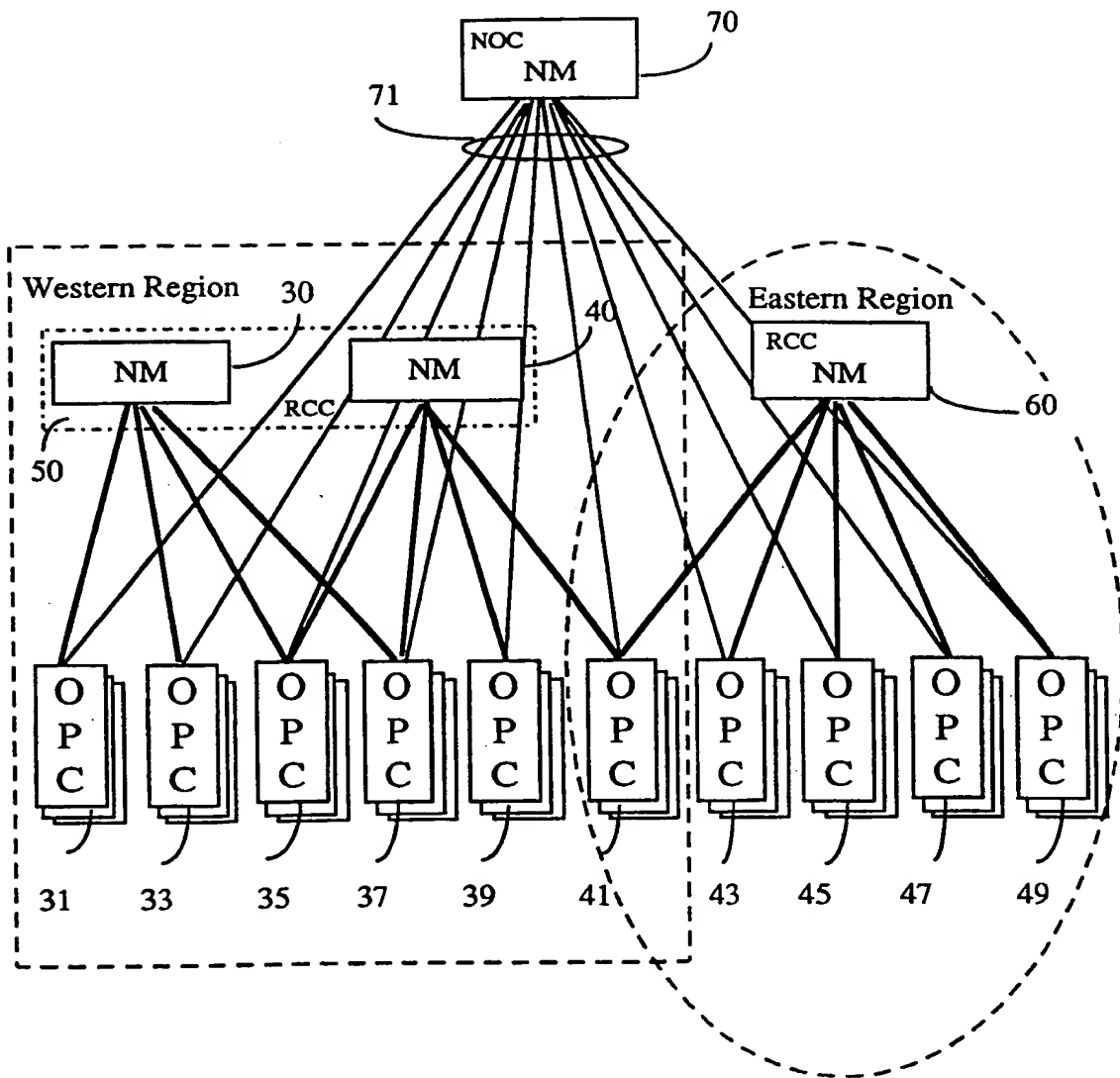


FIGURE 4A



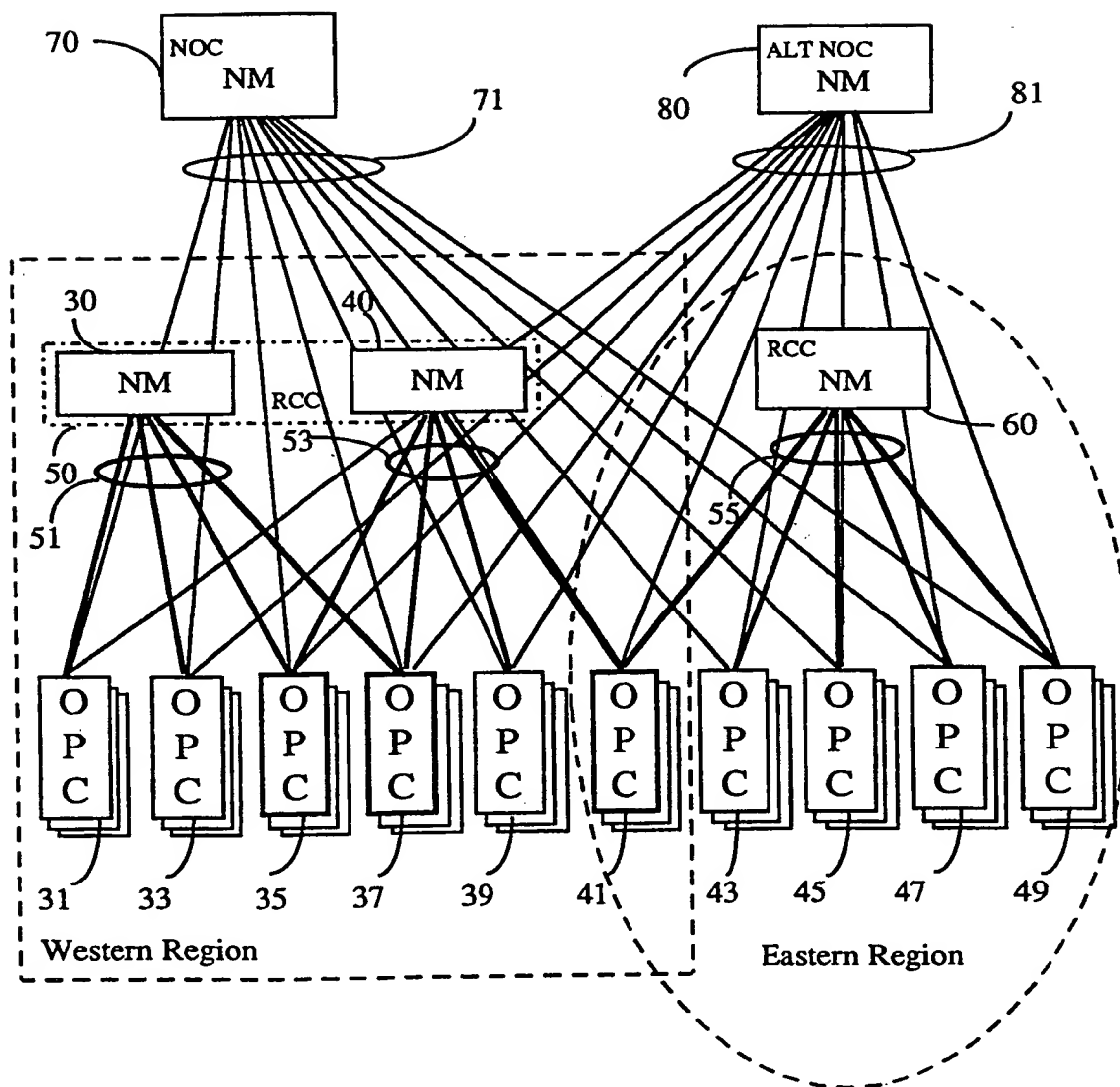
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FIGURE 4B



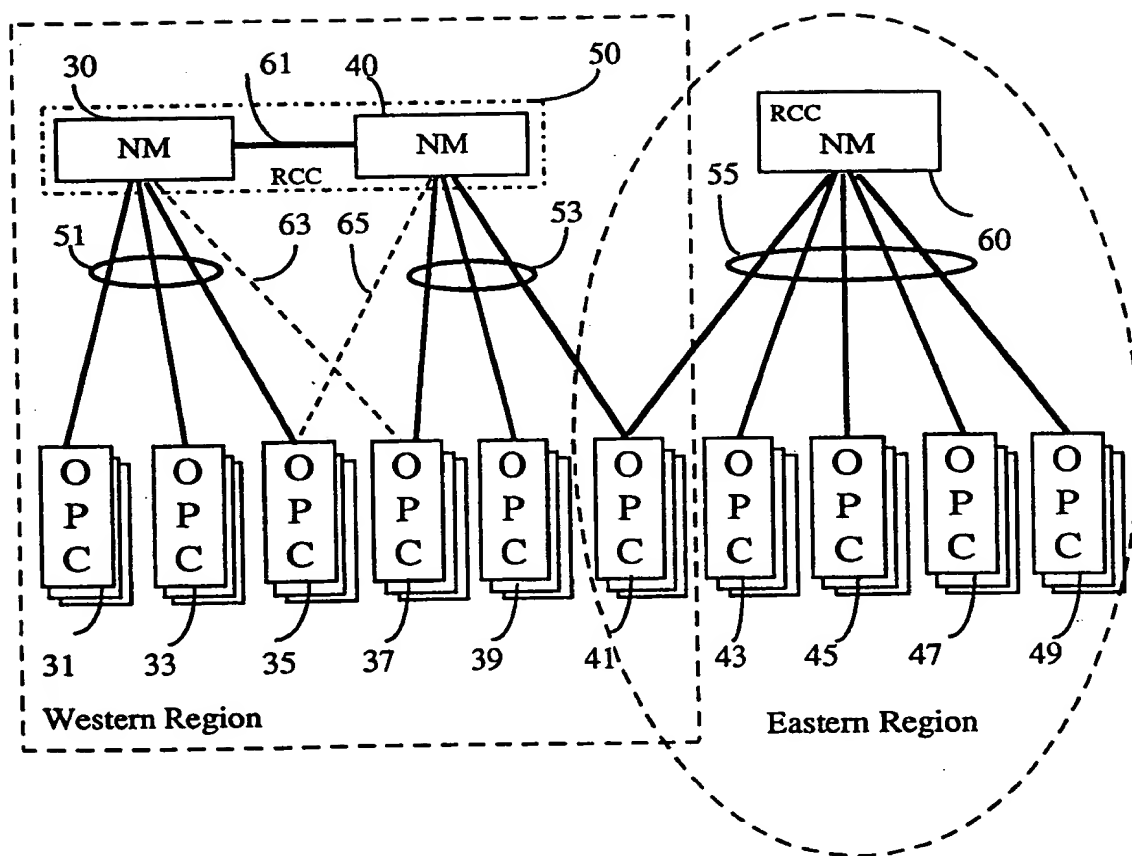
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FIGURE 4C



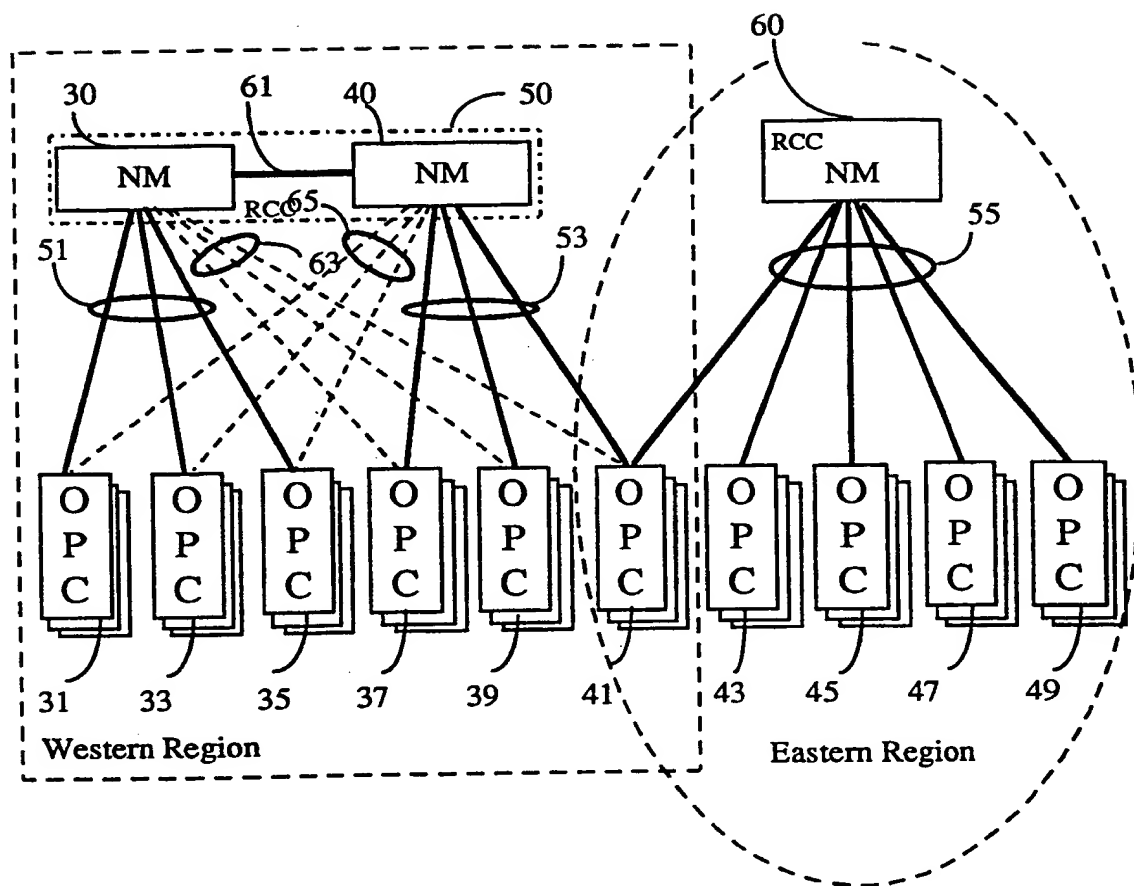
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FIGURE 5A



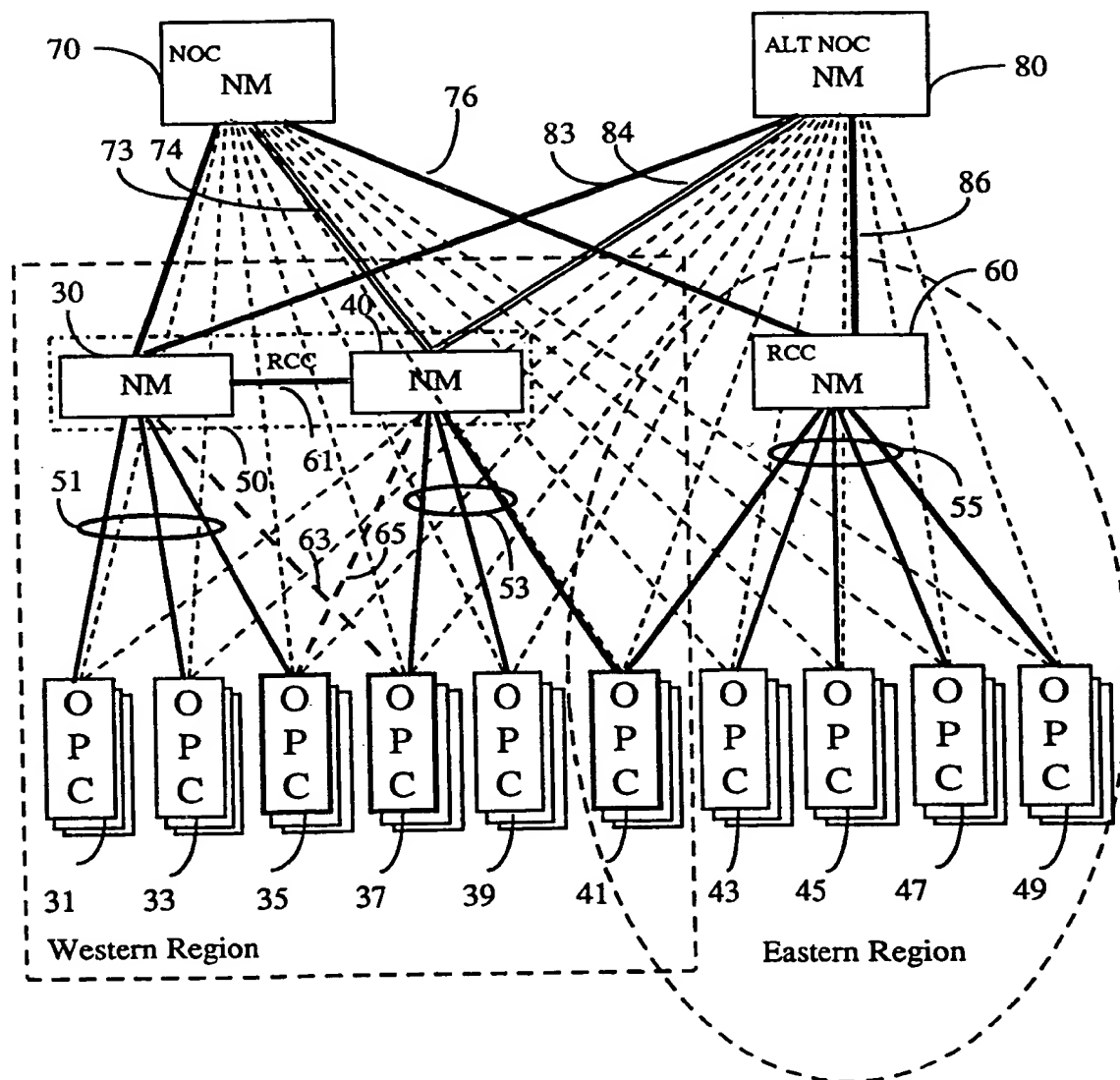
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FIGURE 5B



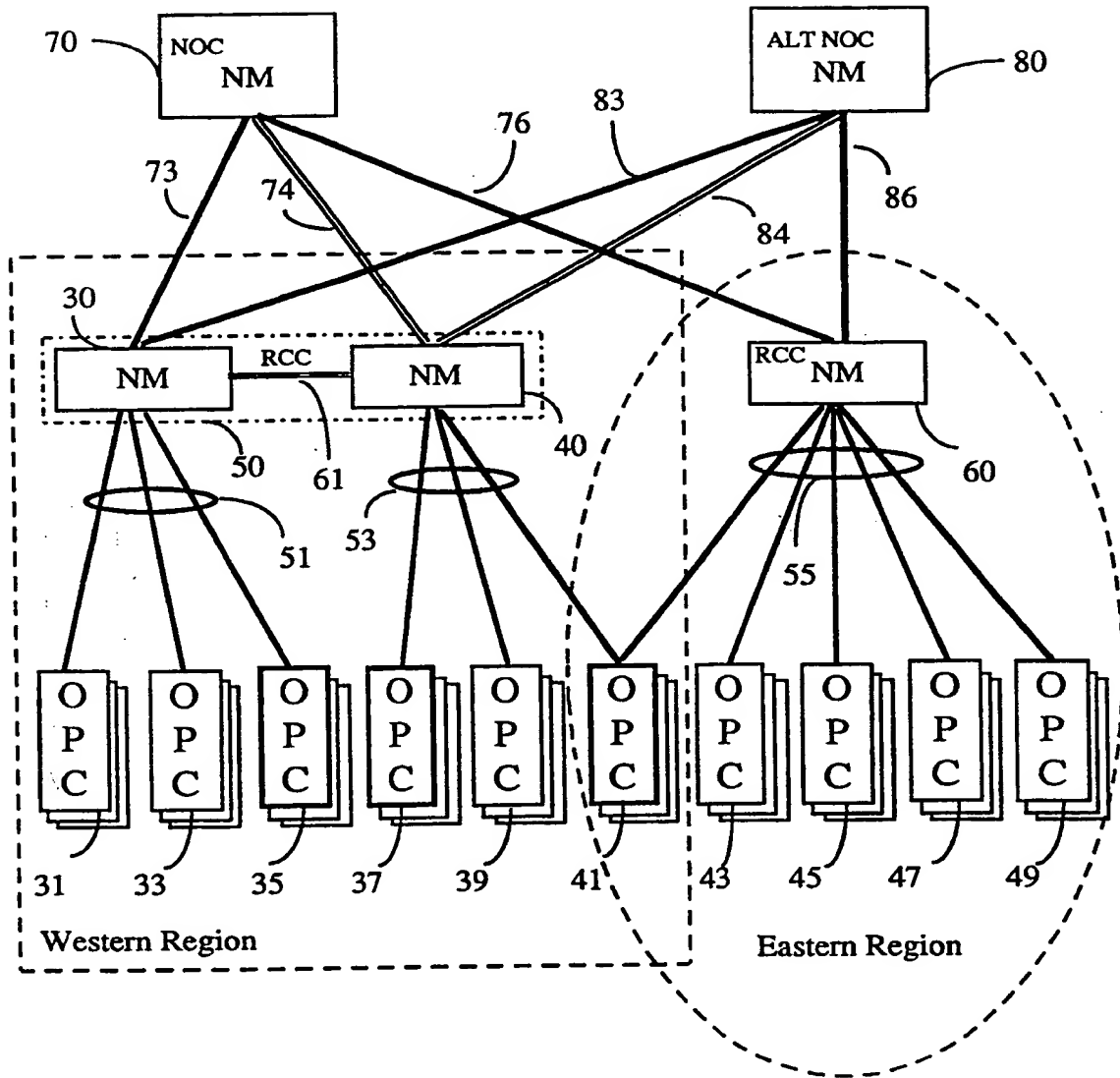
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FIGURE 6A



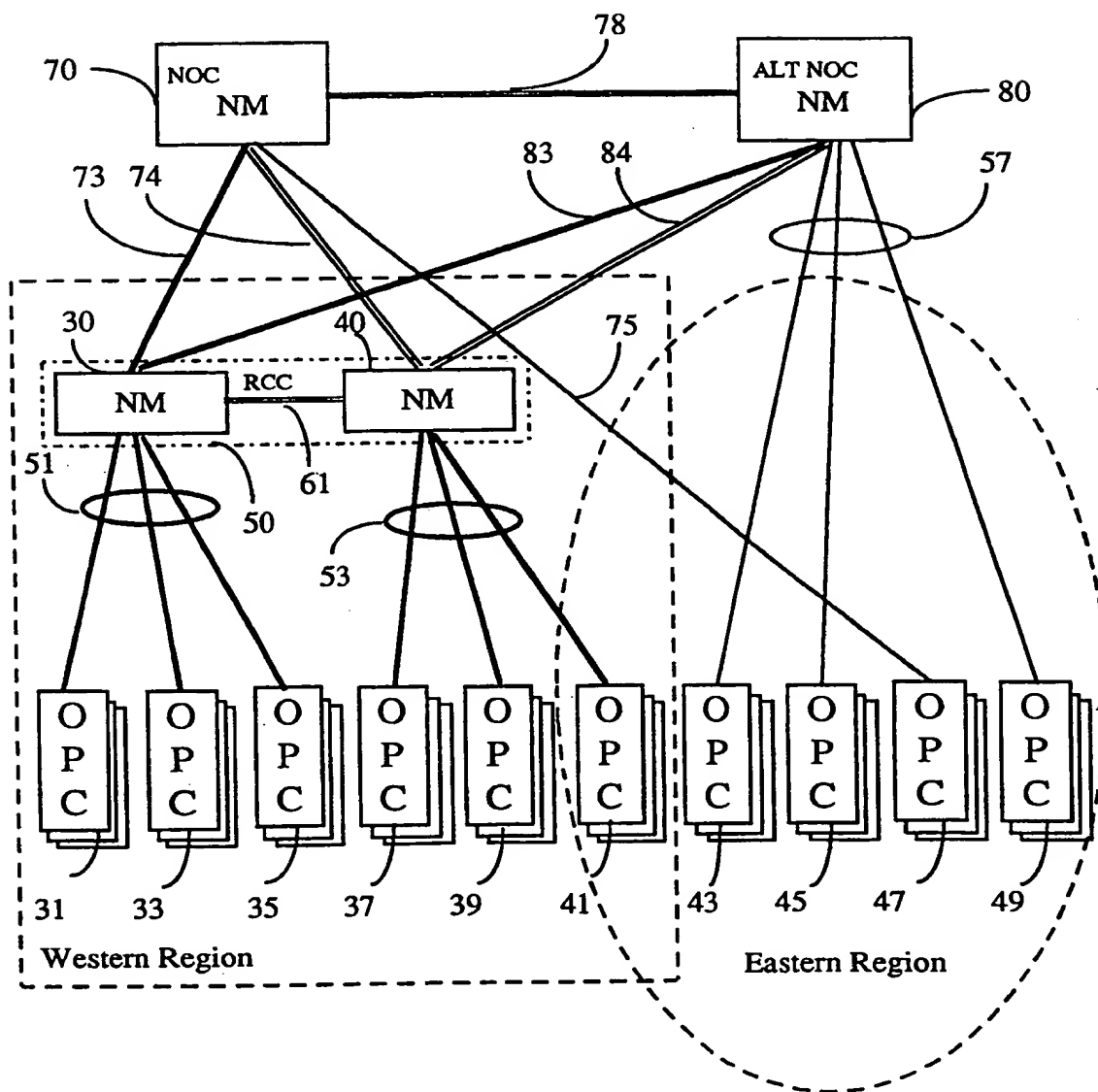
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FIGURE 6B



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FIGURE 7



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FIGURE 8

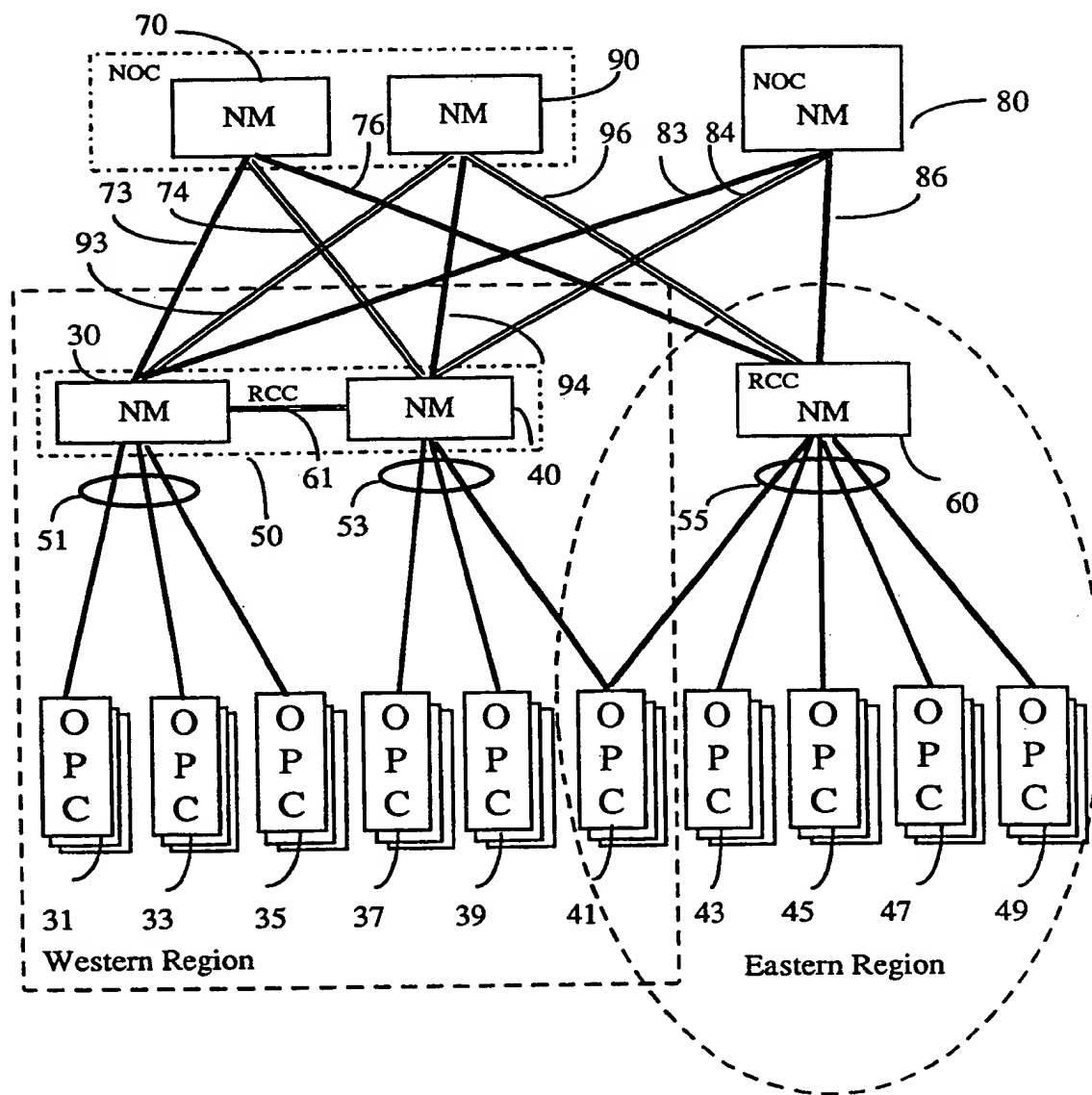
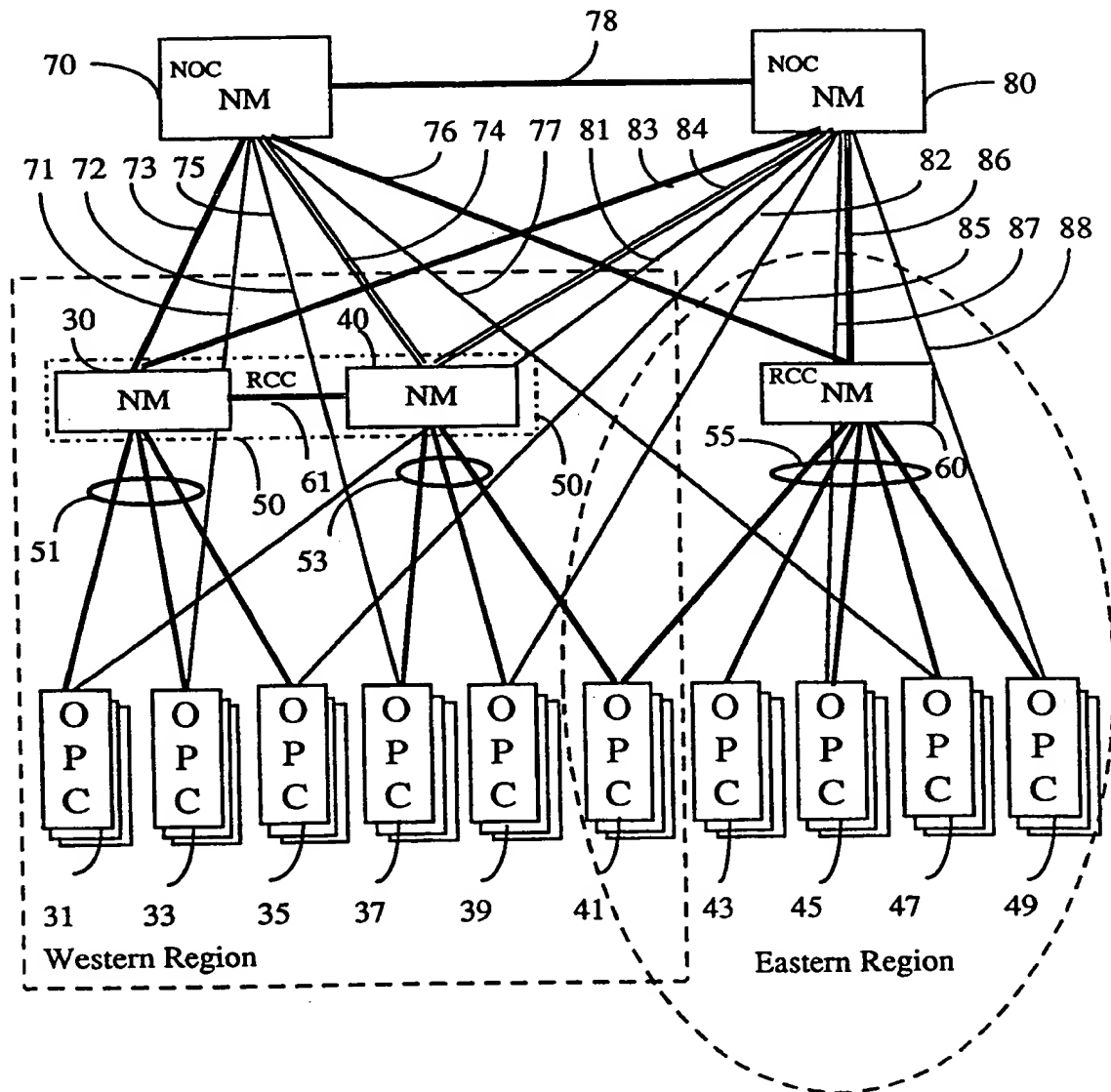
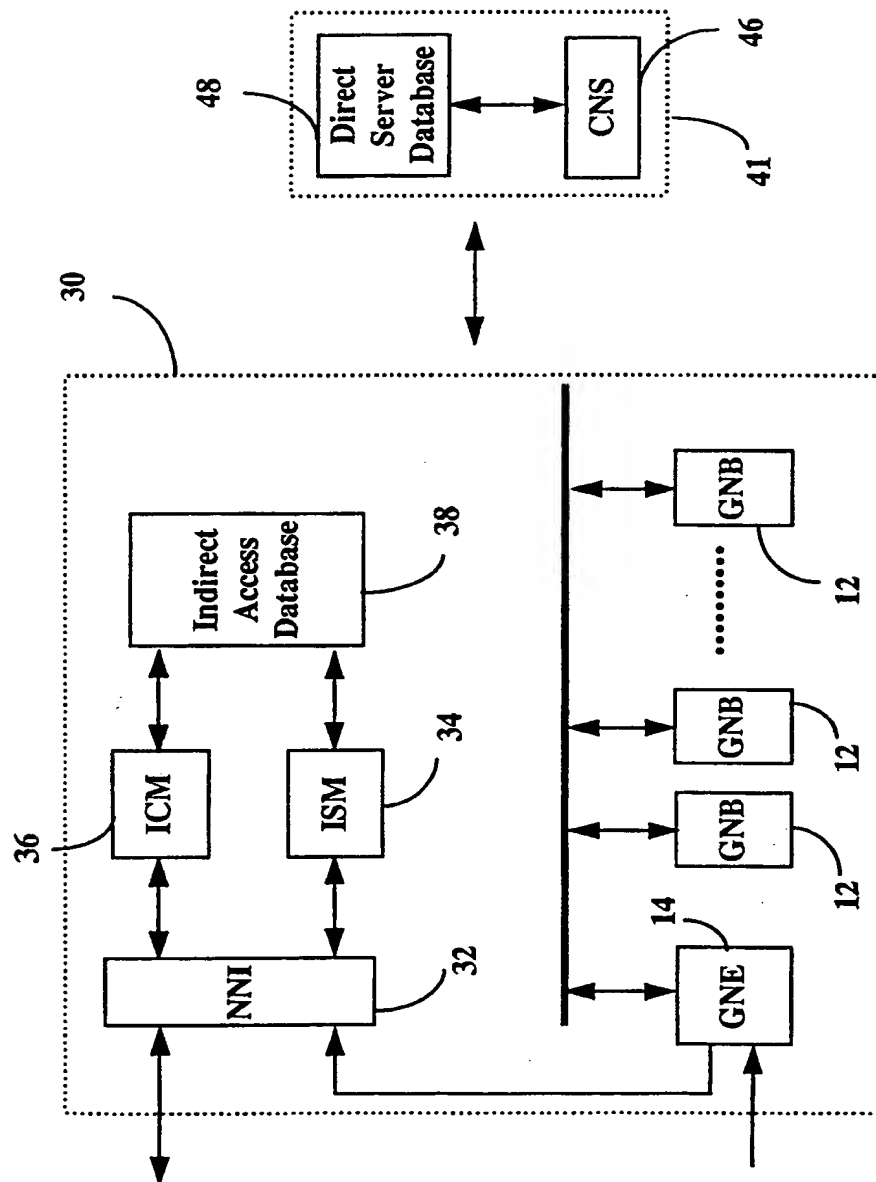


FIGURE 9



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FIGURE 10

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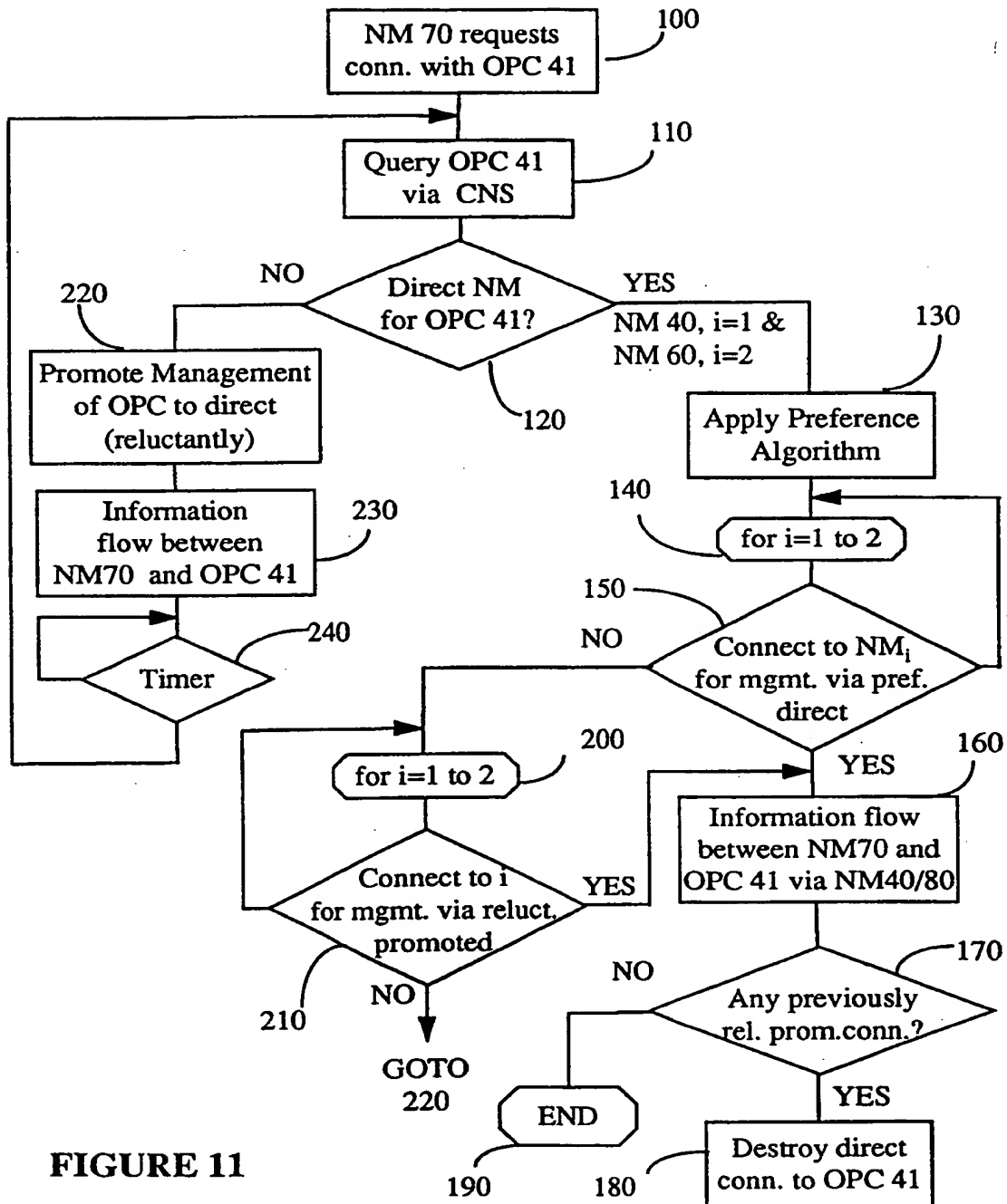
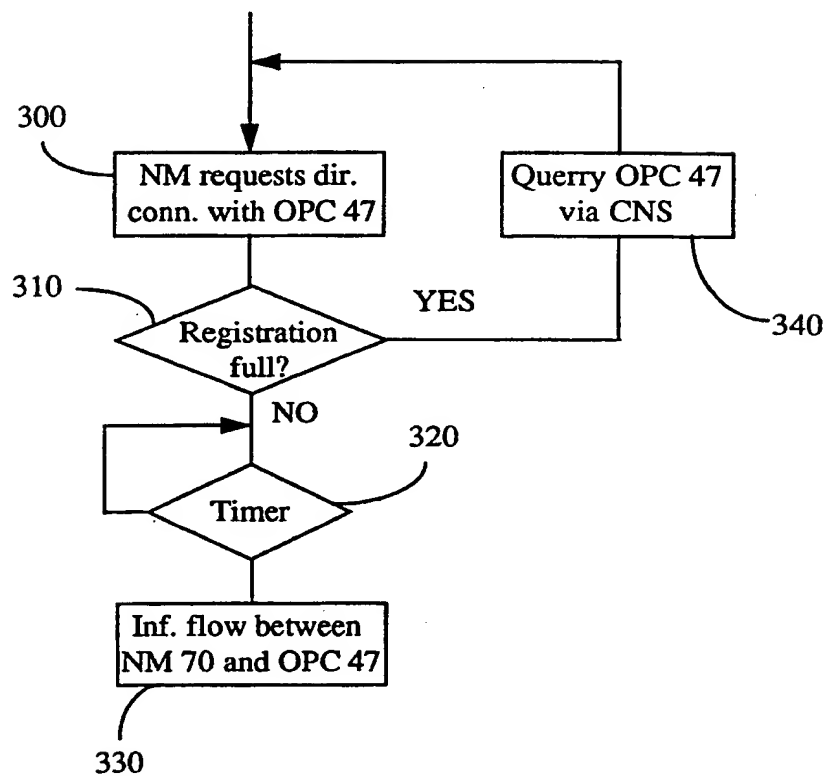


FIGURE 11

FIGURE 12



INTERNATIONAL SEARCH REPORT

Intern. Application No

PCT/CA 98/00543

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H04L12/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	VASSILA A ET AL: "INTRODUCING ACTIVE MANAGED OBJECTS FOR EFFECTIVE AND AUTONOMOUS DISTRIBUTED MANAGEMENT" BRINGING TELECOMMUNICATION SERVICES TO THE PEOPLE - ISS & N 1995, THIRD INTERNATIONAL CONFERENCE ON INTELLIGENCE IN BROADBAND SERVICE AND NETWORKS, HERAKLION, CRETE, OCT. 16 - 19, 1995. PROCEEDINGS, no. CONF. 3, 16 October 1995, pages 415-429, XP000593492	1
A	CLARKE A; CAMPOLARGO M; KARATZAS N (EDS) see page 419, line 3 - page 420, line 14 see paragraph 4 --- -/--	2-24

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search

8 October 1998

Date of mailing of the international search report

19/10/1998

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INTERNATIONAL SEARCH REPORT

Intern. Appl. Application No
PCT/CA 98/00543

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	see paragraph 3.2 see paragraph 3.3	2-24
A	SHIM Y -C: "DEVELOPING A MANAGED SYSTEM IN A TELECOMMUNICATION MANAGEMENT NETWORK" 1996 IEEE INTERNATIONAL CONFERENCE ON COMMUNICATIONS (ICC), CONVERGING TECHNOLOGIES FOR TOMORROW'S APPLICATIONS DALLAS, JUNE 23 - 27, 1996, vol. 1, 23 June 1996, pages 17-21, XP000625634 INSTITUTE OF ELECTRICAL & ELECTRONICS ENGINEERS see paragraph 2.1 see paragraph 3	1-24
A	US 5 448 724 A (HAYASHI YOKO) 5 September 1995 see abstract see column 2, line 4 - line 24	1,4,10

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/CA 98/00543

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